

# Galaxy Clusters with Swift/BAT:

## Questioning the Non-Thermal Emission

by Paola Rebusco



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PREPRINT *Ajello et al 08*: space.mit.edu/home  
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# An Open Question



- **Extended Radio Emission** (e.g. Wilson 70, Dennison 80, Giovannini et al 93-00, Kempner&Sarazin 01, Govoni et al 01, Thierbach et al 03)
- **EUV excess** (e.g. Lieu et al 96, Bowyer et al 99, Bonamente et al 01-02 Bowyer&Berghofer 99, Durret et al 02)
- **Soft excess** (e.g. Bonamente 03-05-07, Nevalainen 03, Werner et al 07)



Is there any non-thermal **X-ray** component?

- {
- Yes:** (e.g Fusco-Femiano et al 99-03-04, Rephaeli 01-02, Gruber&Rephaeli 02, Nevalainen et al 01-04, Eckert et al 07, Lutovinov et al 08)
  - No:** (e.g Molendi&De Grandi, De Grandi&Molendi 99, Revnivtsev 04, Rossetti&Molendi 04-07, Ota et al 08)



- **BAT survey:** 10 clusters detected 15-55 keV

# The Burst Alert Telescope

- Coded mask telescope (15-200 keV)
- 5200 cm<sup>2</sup> detecting area
- PSF 22 arcmin
- Pos. accuracy 1-5 arcmin
- FOV of 2.5 sr (120° x 90°)

*Swift* satellite  
(Gehrels et al 2004)



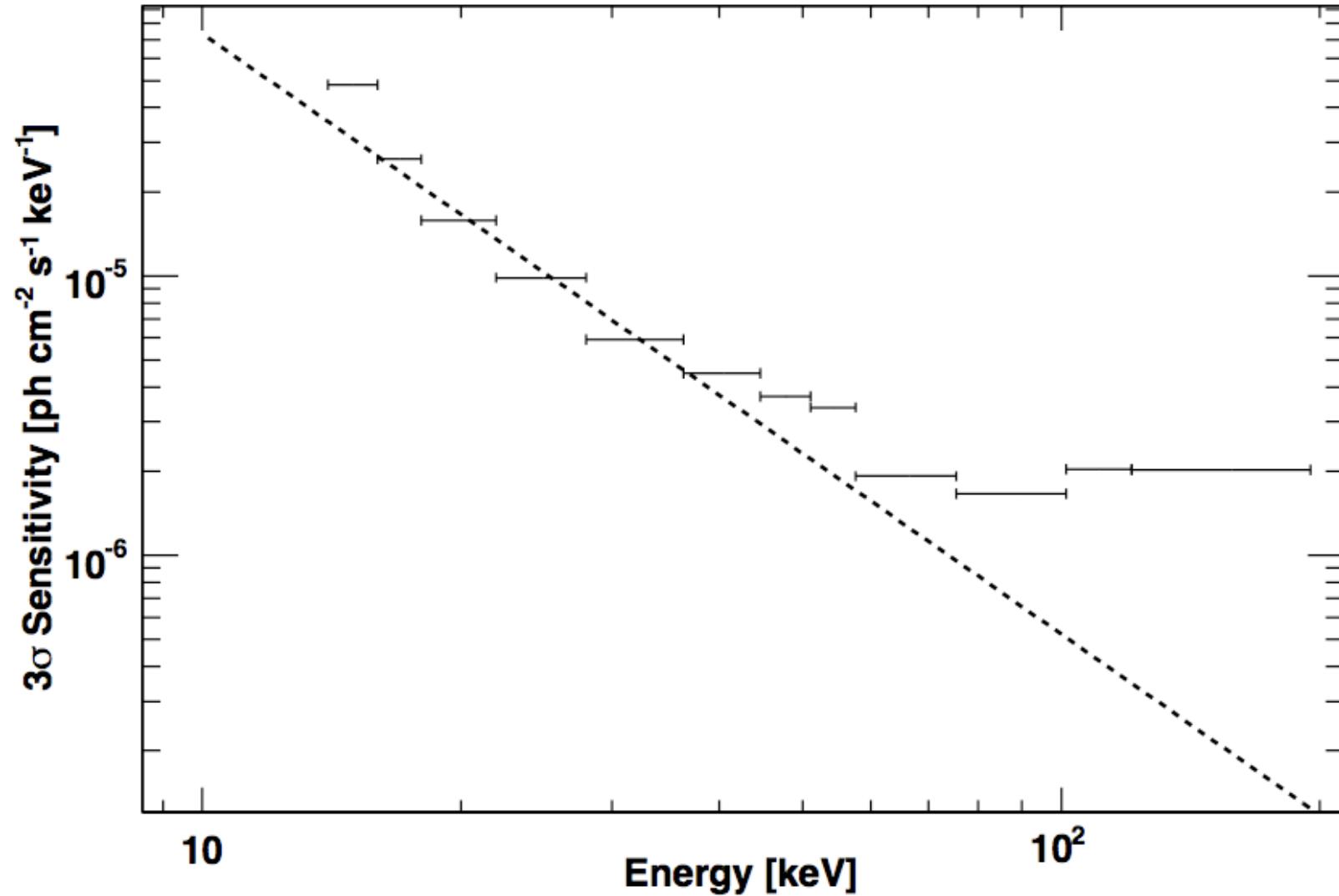
# The BAT X-ray All-Sky Survey

(Ajello et al 2008 a,b-Tueller et al 2008-Winter et al 2008)



- 27 months -> average exp time 3 Ms
- Sources: excesses above  $5\sigma$   
Identification: cross-correlation with the ROSAT catalogue (70%)+ Swift/XRT+ESO follow-up
- Spectrum: 15-195 keV for each obs, corrected for bckg contamination and vignetting and averaged
  
- Coded Mask Telescope ->Optimized for the study of point-like sources *I.e.* that extend below the projection of the mask tile

# What's the Spectral Sensitivity?



Derived by the analysis of >160 source free regions

# Hard Tail to Hunt



- ❖ **IF** a NT component exist, it could arise from:

Population of point sources (e.g. Katz '76, Fabian '76, Fujita 07),  
Inverse Compton (**IC**) on CMB photons (e.g. Rephaeli '79, Sarazin  
99), NT-bremmstr (e.g. Sarazin 99-00), synchrotron emission  
(e.g. Timokhin et al 04, Inoue et al 05, Eckert et al 07)

- ❖ 50-100 keV
  - BAT DATA: no assumption

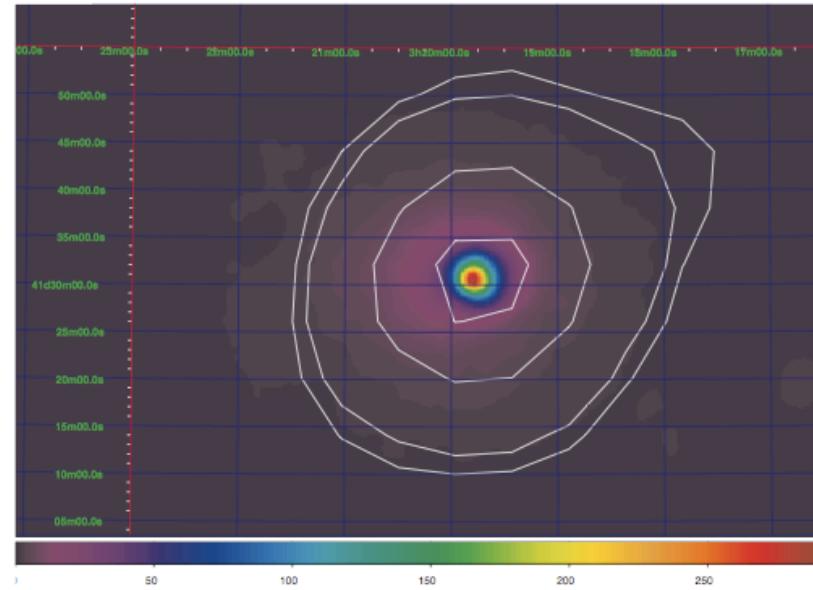
- BAT+XMM/XRT/Chandra: assuming a PL with photon index 2 (e.g. Reimer et al 2004)



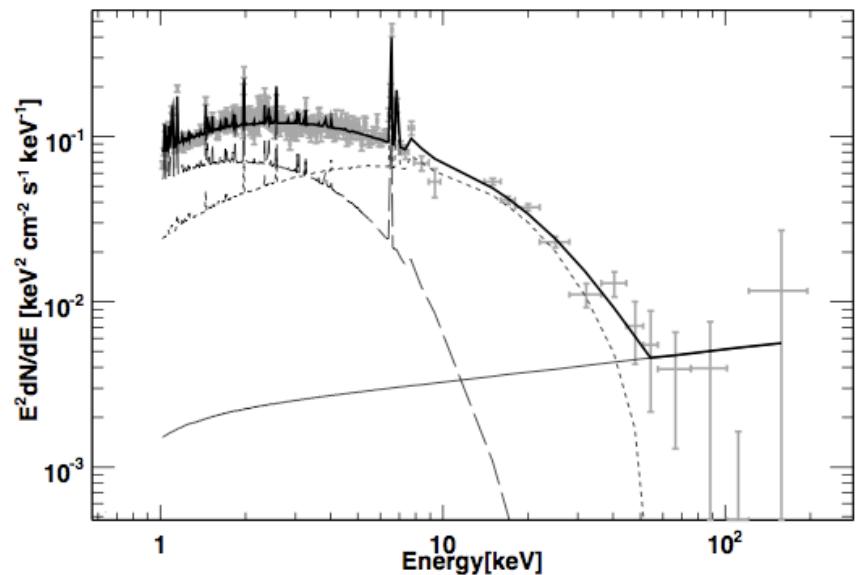
# Which Clusters?

NAME	CC <sup>a</sup> ?	Merger ?	F <sub>50–100 keV</sub> <sup>b</sup> (10 <sup>-12</sup> erg cm <sup>-2</sup> s <sup>-1</sup> )	3 σ limit on the NT flux
Perseus	y	y	...	
Abell 3266	n	y	<5.30	
Abell 0754	n	y	<6.50	
Coma	n	y	...	
Abell 3571	y <sup>d</sup>	n <sup>e</sup>	<11.5	
Abell 2029	y <sup>d</sup>	y	<4.83	
Abell 2142	y <sup>f</sup>	y	<5.35	
Triangulum Australis	y <sup>f</sup>	y <sup>f</sup>	<4.65	
Ophiucus	n	y	<5.89	
Abell 2319	y <sup>d</sup>	y	<3.41	

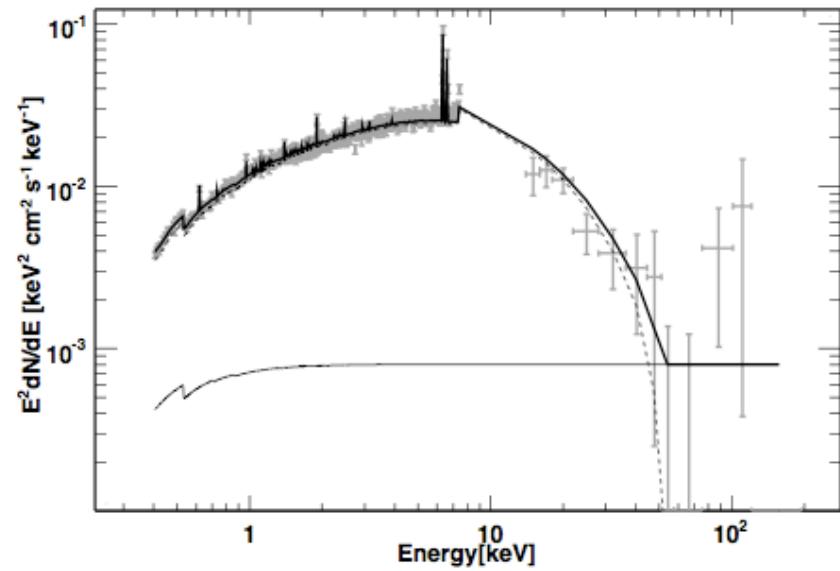
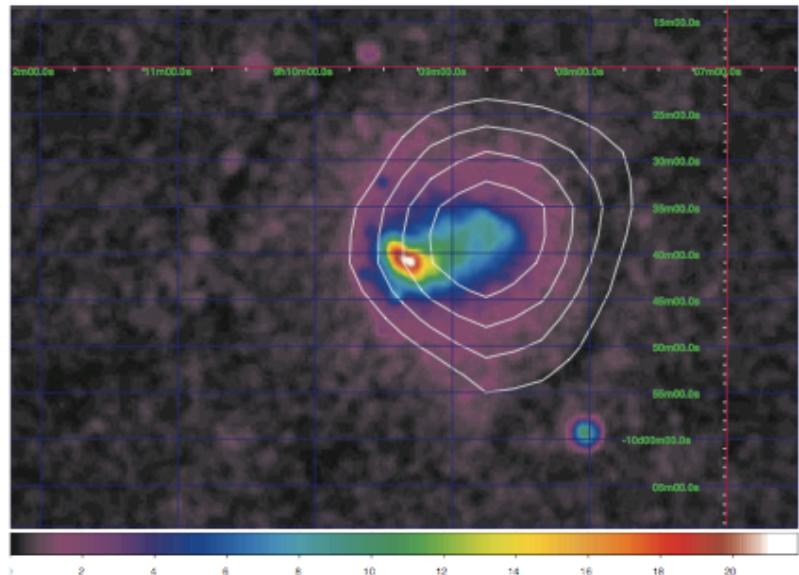
Perseus



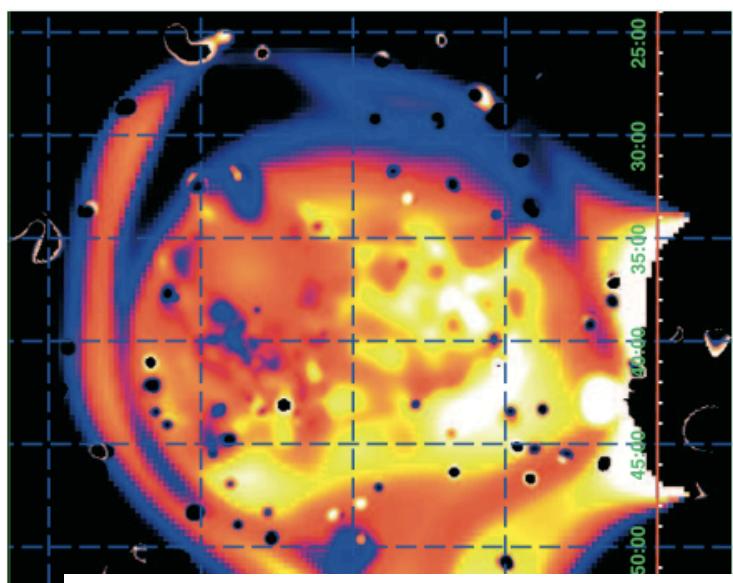
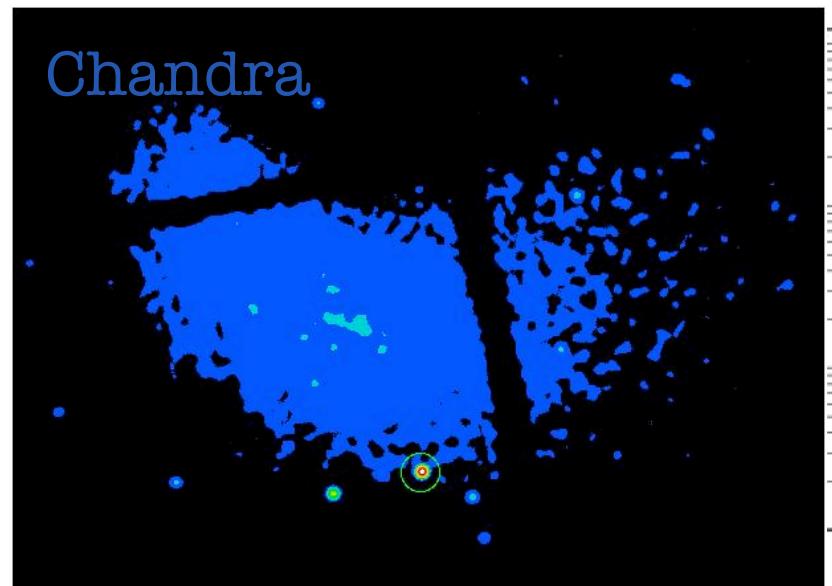
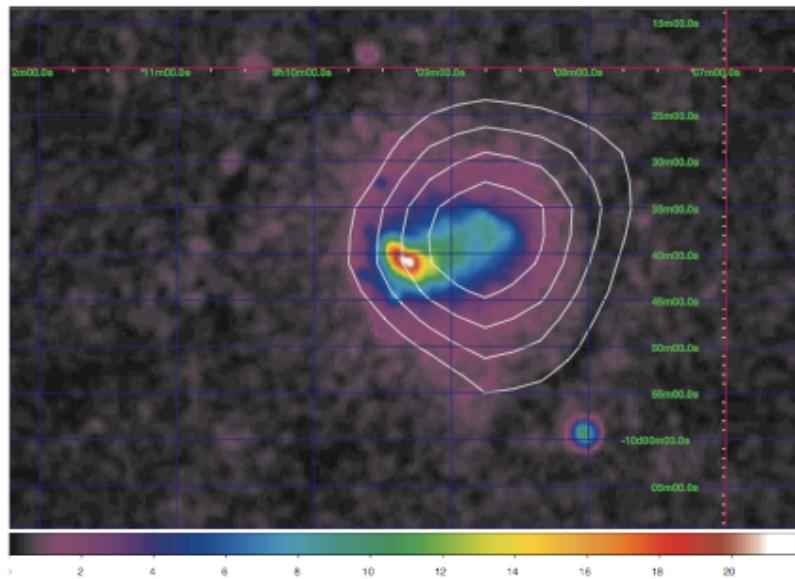
NT Component?!?



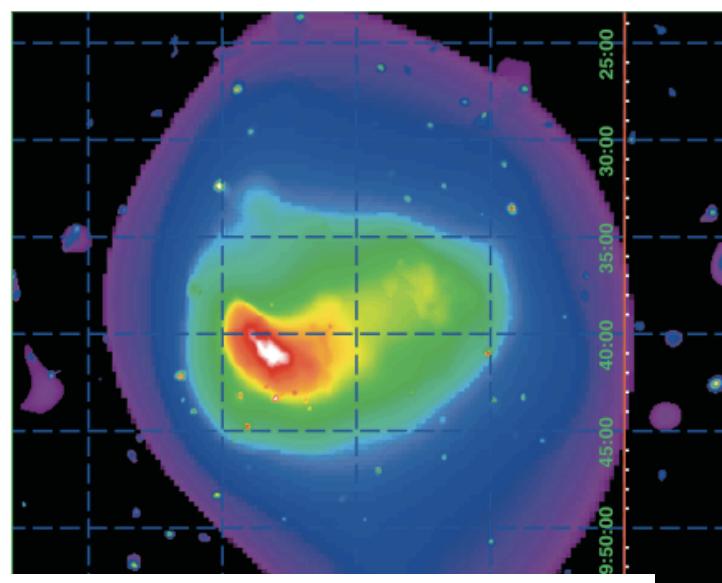
Abell 0754



# Abell 0754



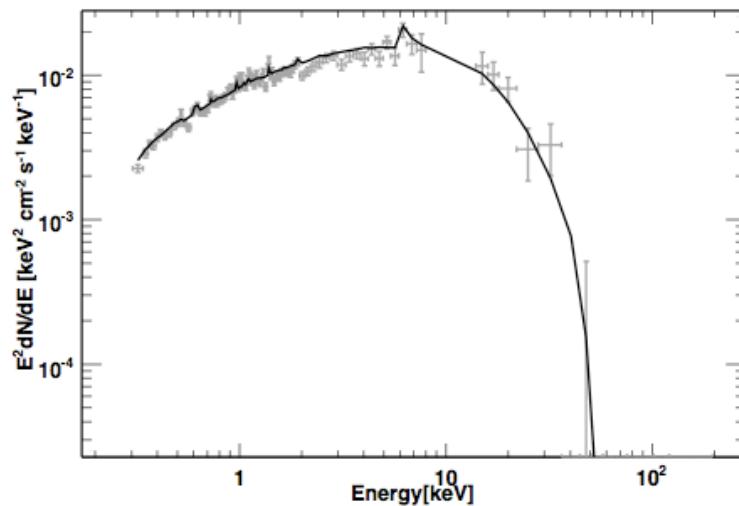
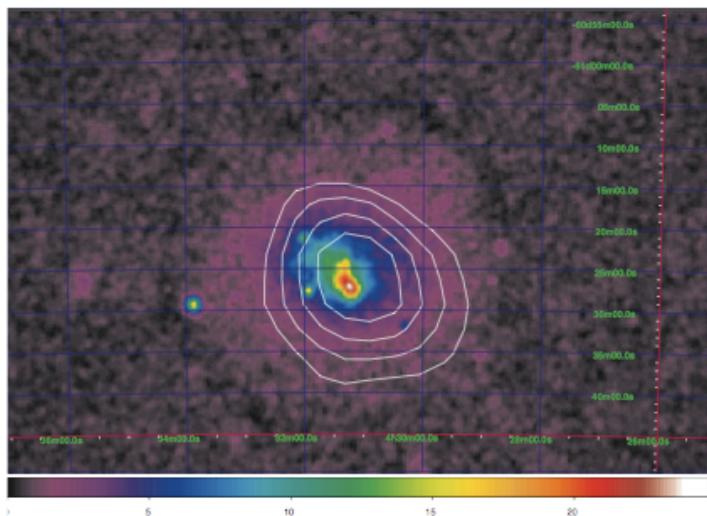
Temperature map



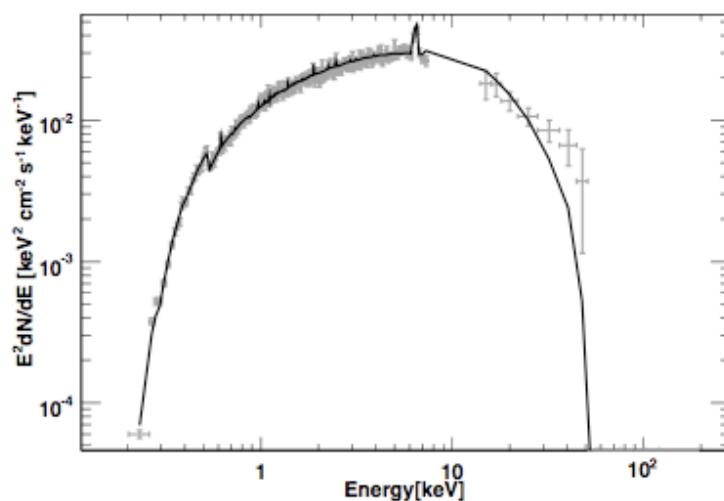
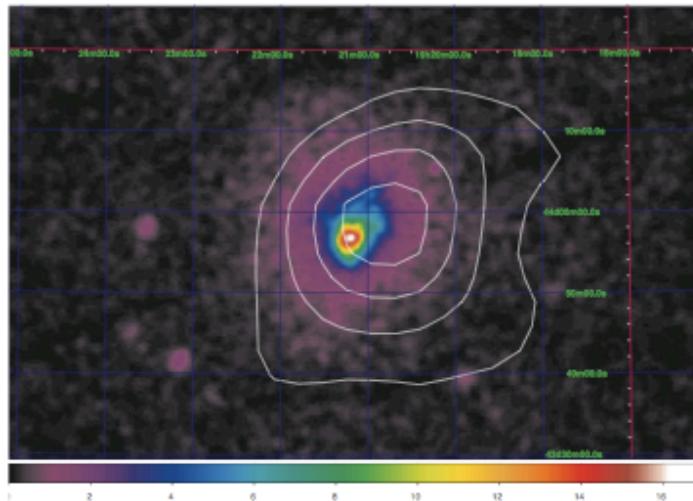
0.8-2 keV map

Henry,Finoguenov&Briel04

## Abell 3266



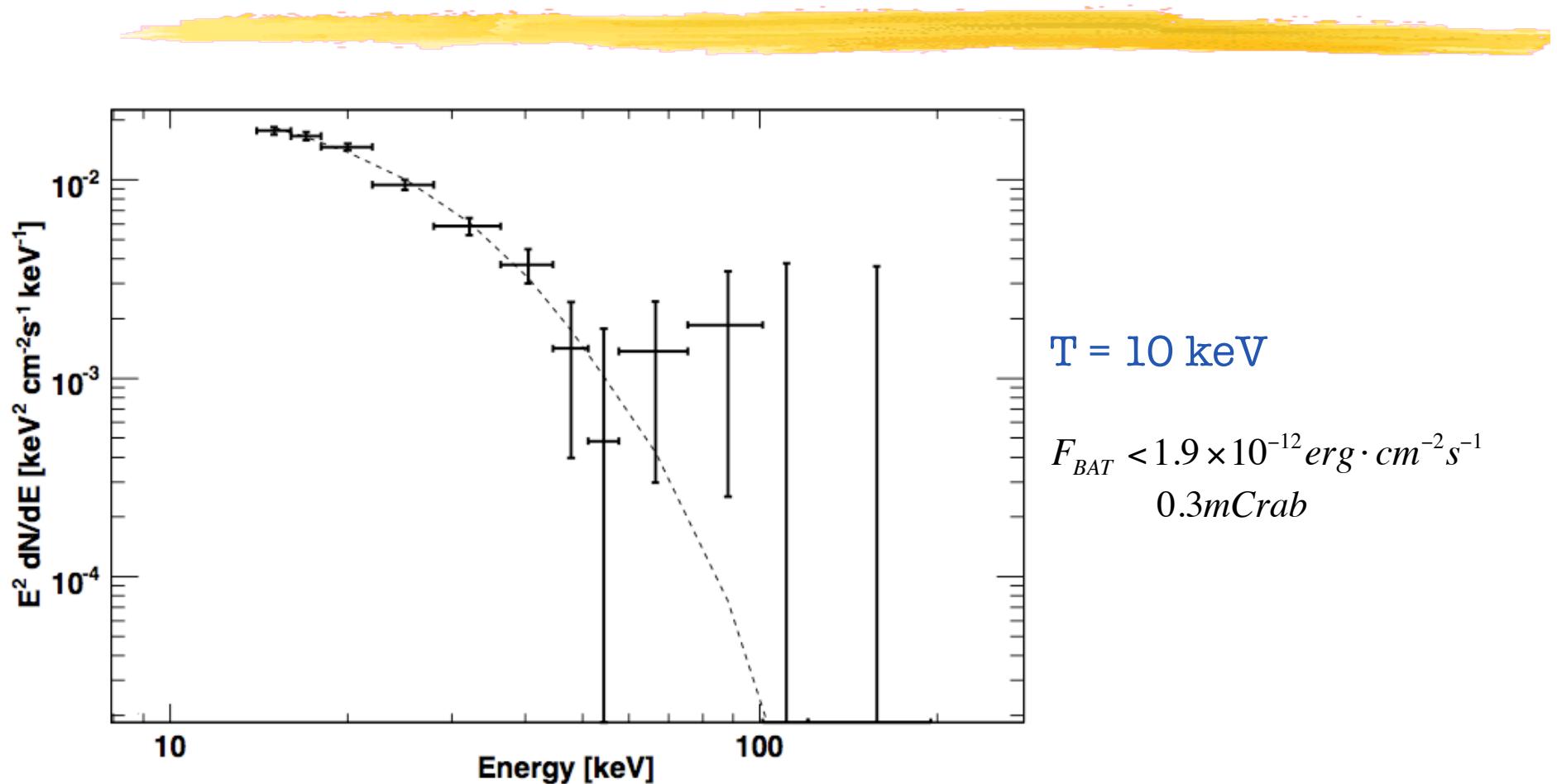
## Abell 2319



## Comparison with previous detections

CLUSTER	INSTRUMENT	AGREE?
Perseus	HEAO1/RXTE/BeppoSAX	✓ AGN
A 3266	--	
A 0754	BeppoSAX	✗ AGN!
A 3571	--	
A 2029	--	
A 2142	BeppoSAX	✗
Triangulum A.	--	
Ophiucus	Integral/BeppoSAX	✗
A 2319	RXTE	✗

# Stacking Analysis



# BAT and Galaxy Clusters



- NO evidence for NT ICM emission  
MAYBE below or at the limit of the CURRENT BAT sensitivity?
- What do these clusters have in common?  
MERGERS!

# INTERMEZZO: Theoretical Scenario

- Standard hierarchical structure formation - cluster latest to virialize



- Merger + accretion of DM and gas **SHOCKS+turbulence** that
  1. can heat the ICM up to 15 keV (Takizawa99, Ricker&Sarazin01, Markevitch+03)
  2. can accelerate particles on scale of Mpc (radio) (e.g. Petrosian&Bykov08)  
CRs make IC on CMB photons --> power-law in the keV range

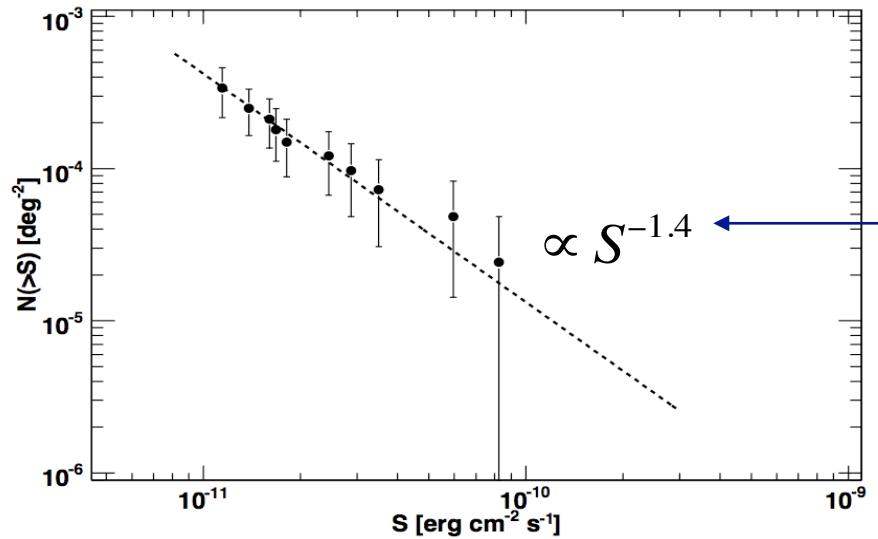
$$\frac{F_{IC}}{F_{Sync}} \sim \frac{1}{B^{\alpha+1}}$$

(e.g. Harris&Romanishin 74)

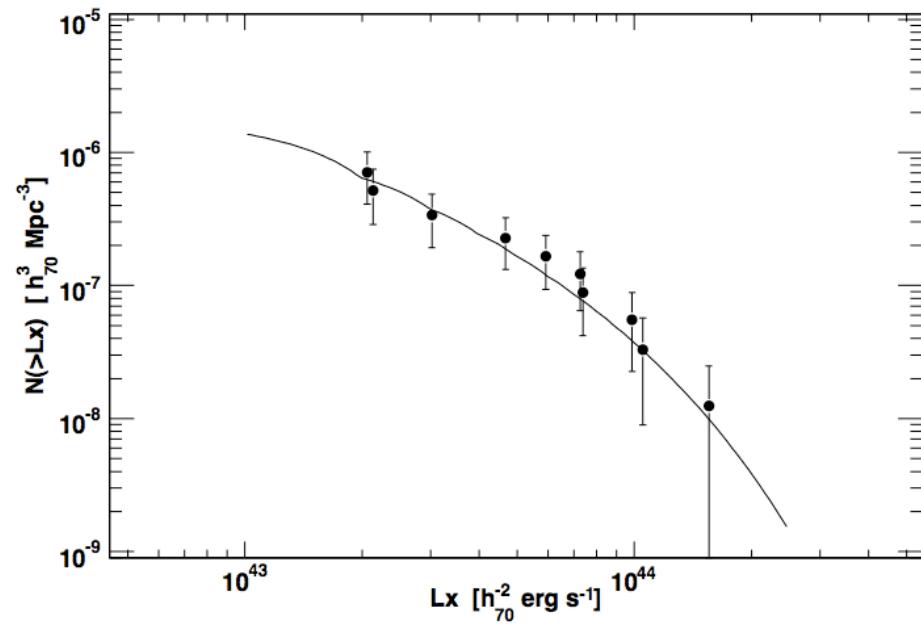
NAME	B	B <sup>b</sup>	
	(μG)	(μG)	
Perseus	...	...	
Abell 3266	> 0.17	> 0.55	XMM
Abell 0754	> 0.10	...	
Coma	...	...	
Abell 3571	> 0.03	~ 0.08	XMM
Abell 2029	> 0.25	> 0.42	XRT
Abell 2142	> 0.06	> 0.10	XMM
Triangulum Australis	> 0.17	> 0.39	XMM
Ophiucus	> 0.11	> 0.38	Chandra
Abell 2319	> 0.10	> 0.15	XMM

B closer to RM- Used in the simulation by Pfrommer08 ->low IC!

# First Source Count+Luminosity Function above 15 keV



Jones et al 98, Boehringer et al 01



CFR REFLEX  
SURVEY

(Boehringer et al 02)

# Conclusions

PREPRINT *ARC08*: space.mit.edu/home/pao



- No significant ( $\geq 2\sigma$ ) non-thermal emission  
(nor single spectra nor stacked)
- Perseus - A0754 have a hard tail
- Assuming IC, magnetic field  $>0.1 \mu\text{G}$  ( $0.5 \mu\text{G}$ )
- Independent analysis: T. Okajima et al. 2008 (in preparation)
- FUTURE: more BAT (on-going survey- if reach 0.5 mCrab->30 clusters)
  - X-ray (Simbol-X/NuSTAR/NeXT)
  - Gamma (GLAST )